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OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

7TH SYMPOSIUM ON NAVAL HYDRODYNAMICS, ROME, 25-30 AUGUST 1968

By FREDERICK H. TODD

11 October 1968

UNITED STATES OF AMERICA

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SEVENTH SYMPOSIUM ON NAVAL HYDRODYNAMICS, ROME, 25-30 AUG 1968

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SEVENTH SYMPOSIUM ON NAVAL HYDRODYNAMICS, ROME, 25-30 AUG 1968

INTRODUCTION

The Seventh Symposium on Naval Hydrodynamics was held in Rome, being sponsored by the Marina Militare Italiana, the US Office of Naval Research and the Istituto Nazionale per Studi ed Esperienze di Architettura Navale, with the collaboration of the Consiglio Nazionale delle Ricerche.

The delegates were welcomed at the opening ceremony by Prof. Luigi Gui of the Ministro della Difesa, Capt. C.T. Froscher, USN, Commanding Officer of the US Office of Naval Research Branch Office, London, representing Rear Admiral Thomas Owen, USN, Chief of Naval Research, and Prof. E. Castagneto of the Consiglio Nazionale delle Ricerche.

Capt. Froscher said that these symposia, sponsored primarily by ONR, have been one way of the Office's "fulfilling its mission of insuring maximum contributions of basic science to naval effectiveness." The first symposium was held in Washington in 1956, and they have since followed at two-year intervals. The first meeting was devoted to general surveys and critical reviews of the state of the art in the various fields of naval hydrodynamics, and each subsequent symposium has had one or more predominant themes. This latest one in Rome was concerned with unsteady propeller forces, fundamental hydrodynamics and unconventional propulsion.

The international character of the symposia has been testified to by the wide range of papers attracted from all maritime countries, and by the fact that alternate meetings have been held in the US and other countries -- Holland in 1960, Bergen in 1964, and Rome in 1968. A list of the symposia and their themes is shown in Appendix I.

In conclusion, Capt. Froscher said that he believed that these symposia have been significant factors in contributing to the progress of hydrodynamics and have become patterns of the type of international scientific interaction that is so greatly needed in today's world of exploding technology. These symposia have helped to generate "the efficient system for the exchange of information and knowledge" called for by President Fanfani in an address to NATO on the "Technology Gap." However, he went on to emphasize that research in itself is not sufficient -- the results must be developed by engineering skills to the point

where they can influence the design of new ships and weapons, and the needs in the application field must in their turn influence future research. In a gathering such as the one in Rome, containing research workers, naval architects and engineers, there was a wonderful opportunity for an exchange of views which could not but exert a beneficial influence on the future.

ATTENDANCE

The Symposium was attended by some 260 delegates representing 24 countries. Among the larger delegations were those from France (20), West Germany (14), Great Britain (26), Italy (54), the Netherlands (15), and USA (80). Eastern bloc countries included Poland (1), USSR (5), and Yugoslavia (2).

PAPERS

There were four formal sessions, each lasting from 0800 to 1400 or later, at which 35 papers were presented. The titles and authors are listed in Appendix II, and they will eventually be published, with discussions, in the proceedings of the Symposium. No attempt will therefore be made to summarize the papers, but attention will be drawn to a few of the more general matters of interest.

The opening paper in the session on "Unconventional Propulsion" was given by Mr. A. Silverleaf, a Deputy Director of the National Physical Laboratory, England. It was illustrated by a wealth of diagrams and tables, but unfortunately no pre-prints were (or are yet) available. He began by calling attention to the many recent changes in the merchant and military navies and the development of such special types as hydrofoils and hovercraft. As a result, there was a great interest in new forms of propulsion, and the designer was faced with difficult, even embarrassing, choices. In Silverleaf's opinion, too many papers emphasize only one aspect of such new devices -- such as hydrodynamic performance or susceptibility to cavitation -- and neglect equally important aspects such as low cost, compactness, weight and reliability. In making a selection, each type of propulsion and engine should be considered from all these points of view. While new, unconventional types of craft may need new types of machinery and propulsors, it is highly desirable to remember

that for the vast majority of ships operating today -- perhaps 95 per cent -- the orthodox marine propeller is still the best answer to propulsion problems. In conclusion, he offered an "order of priority" for design criteria:

Type of Ship	
Merchant	Naval
Low capital cost	Reliability
Reliability	Ease of operation
Low fuel cost	Rapid maneuvering
Ease of operation	Compactness
Ease of maintenance	Low weight
Compactness	Low fuel cost
Low weight	Ease of maintenance
	Silence
	Shock resistance

In view of the problems of modern naval warfare, the criteria of silence and shock resistance would seem to merit a higher place in the order of priority than assigned by Silverleaf. His paper contained many large tables and diagrams, which will merit close examination when the printed text is available.

On the subject of fully-cavitating propellers, it was generally agreed that methods of design for non-cavitating propellers, using vortex theory techniques, could not be applied to fully-cavitating types, and designs were based on empirical methods. One particularly urgent matter was to devise a method for design away from the service condition, particularly at the hump or take-off speed in hydrofoil craft. Mr. Bavin, of the USSR, was of the opinion that the only way to design fully-cavitating propellers was to have a theory taking into account the thickness of the cavity. Work at Kiev in 1966 showed that the thickness effect could be taken into account by linear theory, but the method had not yet been used in actual design.

It appeared from the papers and discussions that there were still considerable discrepancies between the hydrodynamic performance and force-generation of propellers as deduced from different theories and as measured on models. Experiments are being conducted at the Naval Ship Research and Development Center to compare the measured forces with those calculated from theories ranging from simple, quasi-steady considerations to those of high sophistication, which many times gave very different results. The USSR delegates indicated that they are also working on these problems.

Prof. Castagneto, discussing the differences in hydrodynamic performance between theory and model tests, said that these differences sometimes amounted to 15%, and emphasized the good advice given by the Netherlands Ship Model Basin that care and prudence should be exercised before handing over such theoretical methods of design to engineers until their correctness was assured, and the latter then needed time to satisfy themselves as to the reliability of the methods. It was evident that further data are needed on the corrections for blade interference and viscosity, and research to this end is in hand in a number of establishments.

Dr. V.E. Johnson of Hydronautics, Inc., gave a very good "state-of-the-art" review of water-jet propulsion. With the advent of high-speed special craft, marine non-cavitating propellers present difficulties in the gearing, and fully-cavitating propellers just manage to "skim by" at the off-design performance of hydrofoil craft. These problems have revived interest in water-jet propulsion, which offers an opportunity of improving low-speed thrust performance at take-off speeds. Dr. Johnson advocates the use of propeller-type pumps for hydrofoil craft up to 35/40 knots, centrifugal pumps above 80 knots, with mixed-flow pumps in the intervening range. He also listed urgent research needs, which are engineering rather than theoretical in nature:

1) Development of a light-weight, cavitation-free pump, which must cater for the influence of non-uniform inflow due to boundary layer and ducting.

2) Hydrodynamic design of inlets, including the effects of non-zero incidence due to pitching moment, boundary-layer ingestion, ram recovery, external drag, cavitation characteristics, air ingestion and off-design performance, with the possible use of variable area.

Dr. E.R. Quandt, of NSRDC Annapolis Division, pointed out that since ships operate at an interface it is conceptually possible to use jet propulsion using air, water or a mixture. He has been doing research on a water-augmented air-jet, which he calls a "mist-jet." In the practical application, a gas turbine can be used to drive a compressor fan in the air inlet, and a water scoop can then supply a water-spray, giving a two-phase nozzle.

The calculated efficiency appeared to be high enough to suggest further development. Dr. Quandt concluded that the work to date suggests that the results are correct within ± 20%; the propulsive efficiency for a water-augmented air-jet can be nearly equal to that of other devices (say 0.50); the jet is of light weight but deals with large volumes; and is inherently amphibious since it can run (and start) on air only. Work on the project is continuing at the Annapolis Division of NSRDC.

In the discussion on Mr. Hadler's paper on partially submerged propellers, Capt. Bindel (French Navy) drew attention to the problem of stopping ships so equipped due to ventilation of the propellers, a decrease in thrust and a consequent increase in the head-reach before coming to rest. Mr. Volpich pointed out that Denny Bros. on the Clyde had used such propellers (called Vane-wheels at the time) some 35 years ago. Model experiments were made in 1930 using circular back blade sections, and a 120-ft ship was built having 6-ft-diameter propellers run at 60 rpm by geared diesels. The best ratio of immersion/diameter was found to be 0.35, and propulsive efficiencies up to 0.48 had been obtained, which compares with about 0.55 for side paddles. Vospers (UK) have found that on racing craft they get higher speeds with semi-submerged propellers having circular back blade sections.

PANEL DISCUSSIONS

In addition to the formal sessions for the presentation of papers, a series of nine panel discussions was arranged in the evenings from 1700 to 2000 hours. They were run in parallel, and were intended to be informal, but in the event they turned out to be more or less extensions of the formal sessions. This was due to a number of causes -- the large numbers attending each panel (up to

60 in some cases); the fact that because of this they had to be held in lecture theaters rather than in a "round table" atmosphere; that each speaker had to go to the microphone to cope with simultaneous English-Italian translations; and lastly, perhaps because most of the delegates were tired after the six-hour morning sessions when eight to ten papers were presented.

The subjects covered by the panels were wave resistance, propeller design, surface effects vehicles, lifting surface theory, ducted propellers, hydrofoil craft, numerical solutions, propeller-ship interaction and planing craft.

In the panel on surface effects vehicles, some interesting figures were given by Aerojet Corporation for propulsive efficiencies:

	Turbo jet	Turbo fan	Blower fan	Fully cavitating propeller	Partly sub-merged propeller	Water jet ram inlet	Water jet flush inlet
Overall propulsive efficiency %	18	23	44	47	60	43	52
	Amphibious Vehicles			Over-Water Vehicles Only			

An opinion was expressed by Aerojet in favor of water jet propulsion for speeds in the 70-80 knot range. Cdr. Skolnick, in the course of some philosophical remarks on the future of high-speed ships, said that we are just at the threshold of new developments in ocean transport above and below water and that the USA has embarked on a program to investigate their feasibility. Ship research has always been short of funds, and the future of marine transportation requires proper planning of an extensive research program. Tools such as systems analysis exist, but are not being used in marine designs. The surface effects vehicle field requires scientists, but eventually will need marine engineers to make it a success. In his opinion, the SES vehicle has passed the test by being worth developing, and the main barrier is now one of attitude and instilling the will to win.

Dr. Weller said that for bulk transport, the low cost of rail and surface ship transport made them supreme. On the other hand, he pointed out, cost alone should not prevent the development of SFS craft if there is a need for them -- cost does not stop the US going to the moon!

In the panel on propeller-ship interaction, Dr. van Manen (Netherlands Ship Model Basin, NSMB) drew attention to the effect of cavitation on the hull propulsion factors, particularly the thrust-deduction coefficient $\underline{t}$. In the tank $\underline{t}$ is reduced with a fully-cavitating propeller by as much as 50% -- i.e., on a full tanker, from 0.2 to 0.1. The reduction in propulsive efficiency due to cavitation is less for ducted propellers than for open propellers. In order to study the effects of cavitation on propulsive efficiency and its factors, using large models run at the correct scale pressure, NSMB are contemplating building a reduced pressure towing tank capable of testing 12-m (39.4-ft) models. The tank would have dimensions of 175 m (575.2 ft), measuring length by 18 m (59.0 ft) by 8 m (26.2 ft). Dr. Kinoshita (Japan) said that occasionally tankers of deadweight greater than 200,000 tons did not quite achieve the speed predicted from tank tests. He attributes this to two principal causes: (1) While the length of such vessels has increased greatly, the speed has not, and there is therefore a tendency for the center of buoyancy to be moved too far forward. (2) The length/beam ratio has decreased to values less than 6.0, which tends to make such ships directionally unstable, so that they pursue a sinuous course at sea, thereby suffering increased resistance.

Mr. Bavin (USSR) stated that since large tankers do not have fully-cavitating propellers, he could not accept the 50% reduction in $\underline{t}$ mentioned by Dr. van Manen -- it must be much less. In the case of propellers in nozzles, he said that the bending moments on the blades can be reduced to one-third of those experienced by non-nozzle propellers, and $\underline{t}$ would be reduced in a wake-adapted nozzle. Mr. Lindgren of the Swedish State Tank agreed with Bavin that NSMB had overestimated the scale effect on $\underline{t}$. If such a large effect existed, it would have been found before. Lindgren pointed out that the new Swedish cavitation tunnel allows the effects of cavitation to be investigated

on 8-m (26.2 ft), self-propelled models. Dr. Morgan (NSRDC) agreed that the effect of cavitation on t for super-tankers could not be of the order quoted by NSMB. At NSRDC some work has been done on calculations of t, breaking it up into its components, and quite encouraging agreement between calculated and measured model values have been found for a body of revolution, with and without appendages, and for a merchant ship.

VISIT TO NATIONAL INSTITUTE FOR HYDRODYNAMIC RESEARCH

A new Institute for Hydrodynamic Research is being built on the outskirts of Rome in the part of the city known as EUR. This is a "new city" originally started before WWII as the site of the Olympic Games. It was subsequently developed as a center of Italian Government administrative offices.

The Italian Navy has installed a cavitation tunnel on the site, which is now operating. It is a standard Kempt and Remmers product.

The National Research Council is building the new hydrodynamic research institute on the same site. Eventually there will be two towing tanks with respective dimensions:

454 m (1490 ft) x 13.5 m (44.3 ft) x 7 m (23.0 ft); and

209 m (685.7 ft) x 9.0 m (29.5 ft) x 4 m (13.1 ft).

The first will have a towing carriage with a top speed of 15 m/sec (49.2 ft/sec), the second a speed of 10 m/sec (32.8 ft/sec). A wavemaker will be installed in the first tank, but the type has not yet been decided.

There will also be a seakeeping tank, but no rotating arm facility.

The long tank is complete so far as concrete work is concerned, and filled with water. The flat, concrete roof is complete, but no walls are erected and the whole plant is a long way from completion.

APPENDIX I

First Symposium - "Naval Hydrodynamics"

Washington, D.C., 24-28 Sep 1956
Sponsor: ONR and National Academy of Sciences/
National Research Council
NAS-NRC Publication 515, 1957, Washington, D.C $5.00

Second Symposium - "Hydrodynamic Noise & Cavity Flow"

Washington, D.C., 25-29 Aug 1958
Sponsor: ONR and NAS/NRC
Superintendent of Documents, Government Printing Office,
Washington, D.C. 20402
Catalog No. D.210.15 ACR 38 $4.00

Third Symposium - "High Performance Ships"

Scheveningen, Holland, 19-22 Sep 1960
Sponsor: ONR and Netherlands Ship Model Basin
G.P.O. Catalog No. D.210.15 ACR 65 $3.50

Fourth Symposium - "Propulsion and Hydroelasticity"

Washington, D.C., 27-31 Aug 1962
Sponsor: ONR and Webb Inst. of Naval Architecture
G.P.O. Catalog No. D.210.15 ACR 92 $6.75

Fifth Symposium - "Ship Motions and Drag Reduction"

Bergen, Norway, 10-12 Sep 1964
Sponsor: ONR and Norwegian Model Basin
G.P.O. Catalog No. D.210.15 ACR 112 $7.25

Sixth Symposium - "Physics of Fluids, Maneuverability, Ocean Waves and Ship Wave Resistance"

Washington, D.C., 28 Sep - 4 Oct 1966
Sponsor: ONR and Davidson Laboratory, Stevens Inst.
of Technology
G.P.O. Catalog No. D.210.15 ACR 136 $7.00

Seventh Symposium - "Unsteady Propeller Forces, Fundamental Hydrodynamics, Unconventional Propulsion"

Rome, Italy, 25-30 Aug 1968
Sponsor: ONR, Marina Militare Italiana and Istituto
Nazionale per Studi ed Esperioenze di
Architettura Navale di Roma

APPENDIX II

List of Papers and Authors

UNSTEADY PROPELLER FORCES

1. "Solution of unsteady marine propeller problems, using a vortex model," by Dr. N. A. Brown (Bolt, Beranek and Newman, Inc.).

2. "On the theory of unsteady propeller forces", by Prof. R. Yamazaki, Kyushu University.

3. "A lifting surface theory of marine propellers", by Dr. P.C. Pien and Mr. J. Strom-Tejsen, Naval Ship Research and Development Center, Washington, D. C.

4. "Experimental and analytical studies on propeller-induced appendage forces", by A. F. Lehman and Dr. P. Kaplan, Oceanics, Inc.

5. "Investigations on the vibratory output of contra-rotating screw propellers", by Dr. R. Wereldsma, Netherlands Ship Model Basin.

6. "Experimental determination of unsteady propeller forces", by Mr. M. L. Miller and Mr. W. Kopko, Naval Ship Research and Development Center, Washington, D. C.

7. "The response of propulsors to turbulence," by Dr. M. Sevik, Pennsylvania State University.

FUNDAMENTAL HYDRODYNAMICS

8. "Recent progress in the calculation of potential flows", by Dr. A. M. O. Smith, Douglas Aircraft.

9. "Naval hydrodynamic problems solved by rheoelectric analogies", by Prof. M. L. Malavard, Director of Research, Ministry of Defence, France.

10. "The numerical simulation of viscous incompressible fluid flows", Dr. C. W. Hirt, University of California, Los Alamos Scientific Lab.

11. "Theoretical studies on the motion of viscous flows", by Paul Lieber, S. M. Desai, L. Rintai, Kirit Yajnik, University of California.

12. "A contribution to the theory of turbulent flow between parallel plates", by Dr. A. S. Iberall, General Technical Services, Inc.

Appendix II (Cont'd)

13. "Numerical experiments on convective flows in geophysical fluid systems", by Prof. S. A. Piacsek, Argonne National Laboratory.

14. "Progress in turbulence theory", by Dr. R. H. Kraichnan, Woods Hole Oceanographic Institute.

15. "Strip theory and power spectral density function application to the study of ship geometry and weight distribution influence on wave bending moment", by Prof. S. Marsich and Dr. F. Merega, Genoa University.

UNCONVENTIONAL PROPULSION

16. "Prospects for unconventional marine propulsion devices", by Dr. A. Silverleaf, National Physical Laboratory, England.

17. "Design principles of cavitating propulsors and development, in terms of these, of screw propellers of higher erosion resistance for the ships "Raketa" and "Meteor"", by Prof. I. A. Titoff, Dr. A. A. Rousetsky and Dr. E. P. Georgievskaya, Kryloff Shipbuilding Research Institute.

18. "Supercavitating propeller theory - The derivation of induced velocity", by Mr. G. G. Cox, NSRDC.

19. "The evolution of a fully cavitating propeller for a high speed hydrofoil ship," by Mr. B. V. Davis, De Havilland Aircraft of Canada, and Dr. J. W. English, National Physical Laboratory, England.

20. "A theoretical and experimental study on the dynamics of hydrofoils as applied to naval propellers", by Prof. E. Castagneto, Univ. of Naples, and T. Col. P.G. Maioli, Centro Esperienze Idrodinamiche della Marina Militare Italiana.

21. "Water jet propulsion", by Mr. V. E. Johnson, Hydronautics, Inc.

22. "Analysis of the propulsion efficiency of an air-water jet (mist-jet) for high-speed ships", by Dr. E. R. Quandt, NSRDC, Annapolis.

23. "Performance criteria of pulse-jet propellers, by Dr. M. Schmiechen, West Berlin Towing Tank.

24. "Design analysis of gas-turbine power plants for two-phase hydropropulsion", by Dr. R. Pallabazzer, Polytechnic of Milan.

Appendix II (Cont'd)

25. "Fluid mechanics of swimming propulsion", by Prof. T. Y. Wu, California Institute of Technology.

26. "Theory of the ducted propeller", by Prof. J. Weissinger and Dr. D. Maass, Technical University Karlsruhe.

27. "Studies of the application of ducted and contra-rotating propellers on merchant ships", by Mr. G. Dyne, Mr. C-A. Johnsson and Mr. H. Lindgren, Swedish State Ship & Experiment Tank.

28. "Comparisons of theory and experiment on ducted propellers", by Dr. W. B. Morgan and Mr. E. B. Caster, NSRDC.

29. "The bladeless propeller", by Prof. J. V. Foa, Rensselaer Polytechnic Institute.

30. "On propulsive effects of a rotating mass", by Prof. A. Di Bella, University of Genoa.

31. "The aerodynamics of sails", by Prof. J. H. Milgram, M.I.T.

32. "Magnetohydrodynamic propulsion for sea vehicles", by Prof. E. L. Resler, Cornell University.

33. "Performance of partially submerged propellers", by Mr. J. B. Hadler and Mr. R. Hecker, NSRDC.

34. "Oscillating bladed propellers", by CAPT S. G. Bindel, Délégation Générale à la Recherche Scientifique et Technique, Paris.

35. "Unusual two-propeller arrangements", by Mr. T. Munk and C. W. Prohaska, Hydro- and Aerodynamics Laboratory, Lyngby, Denmark.

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13. ABSTRACT

The Symposium was arranged jointly by the Marina Militare Italiana, the US Office of Naval Research, and the Istituto Nazionale per Studi ed Esperienze di Architettura Navale. It was the seventh in a series sponsored by the Office of Naval Research, and some 35 papers were read by authors from many countries, the three principal themes being unsteady propeller forces, fundamental hydrodynamics and unconventional propulsion. Twenty-four countries were represented by 260 delegates.

In addition to the formal papers, nine panels were formed for evening discussions of subjects germane to the three themes of the Symposium.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Unsteady propeller forces						
Contra-rotating propellers						
Potential flows						
Rheoelectric analysis						
Viscous flow, sails & sailing rigs,						
Turbulent flow, hydrofoil ships,						
Wave bending moments						
Cavitation, surface effects ships						
Fully-cavitating propellers						
Water-jet propulsion						
Air-water jet propulsion						
Gas turbines, propeller-ship interaction						
Pulse jets						
Ducted propellers						

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